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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H05K 7/20	A1	(11) International Publication Number: WO 98/54941 (43) International Publication Date: 3 December 1998 (03.12.98)

(21) International Application Number: PCT/US98/04527

(22) International Filing Date: 9 March 1998 (09.03.98)

(30) Priority Data:
08/865,811 30 May 1997 (30.05.97) US

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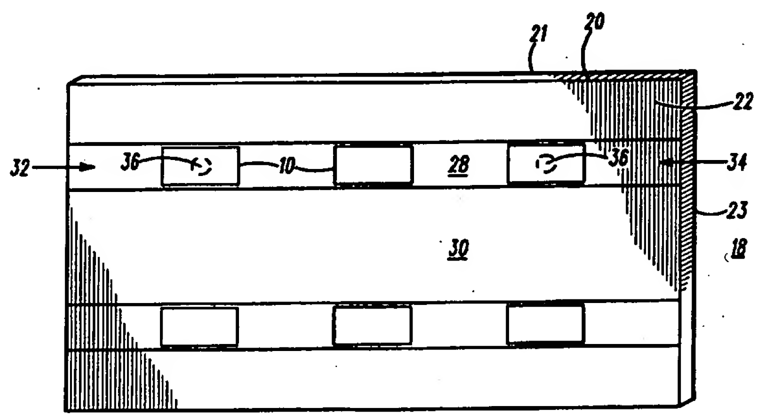
(81) Designated States: AU, BR, CA, CN, JP, KR, MX, SG, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

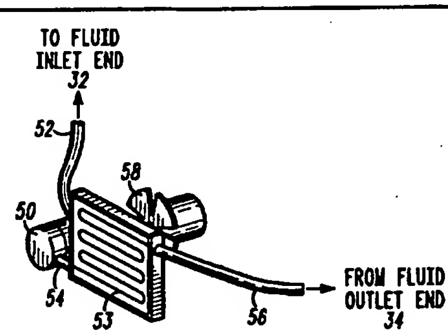
Published
With international search report.

(54) Title: APPARATUS FOR COOLING AN ELECTRONIC COMPONENT

(57) Abstract

The apparatus includes a flexible printed wiring device (18) having a region sized to receive the electronic component (10) and a channel (28) disposed within the flexible printed wiring device. The channel has an inlet end (32) and an outlet end (34) and has an orifice (36) disposed therein. The inlet end receives a fluid, the fluid is distributed to the orifice via the channel and the orifice directs the fluid towards the region, so that the fluid is in direct contact with the electronic component when the electronic component is disposed in the region.





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APPARATUS FOR COOLING AN ELECTRONIC COMPONENT

Field of the Invention

This invention relates generally to cooling heat sources, and, more particularly, to an apparatus and method for cooling an electronic component mounted to a flexible printed wiring device.

Background of the Invention

Electronic components such as integrated circuits, multi-chip modules, passive components and radio frequency (RF) power transistors, which are generally mounted to rigid surfaces such as glass-filled epoxy, alumina, ceramic or plastic circuit boards, may be heat sources which require cooling during normal operation.

Traditionally, electronic components have been cooled by natural or forced air convection, which involves moving large quantities of air past the electronic components, or past heat sinks attached to the components. Advances in electronic devices, however, have resulted in some electronic devices having power densities which exceed the capabilities of traditional natural or forced convective air cooling.

Cold plates, evaporative spray cooling and jet impingement cooling are examples of thermal management techniques which use liquid coolants, rather than air, to dissipate heat generated by electronic components.

The cold plate is typically a direct replacement for an air-cooled heat sink in which water or another fluid flows through internal passages where the heat sink was originally mounted.

It has been proposed to mount heat-producing electronic components to flexible polyimide printed wiring surfaces, and to place the printed wiring surface containing the electronic components directly onto a cold plate.

This technique cools the whole surface of the flexible sheets, however, rather than primary heat sources, such as individual electronic components, located on the surfaces of the sheets. Moreover, the heat transfer capabilities of cold plates may not be adequate for high power electronic devices such as RF transistors, because heat typically must pass through several interfaces before reaching the fluid in the cold plate.

Evaporative spray cooling, or two-phase cooling, features the spraying of atomized fluid droplets directly or indirectly onto a surface of a heat source such as an electronic component. Jet impingement cooling involves directing a high velocity, narrow stream of coolant fluid from an orifice toward the surface of the electronic component to be cooled. When fluid impinges upon the electronic component's surface, the resulting flow field is capable of supporting high heat transfer rates using either single-phase or evaporative cooling.

Although cooling techniques such as spray-cooling and jet impingement cooling are often preferred methods of cooling electronic components mounted to traditional printed circuit boards, the rigid nature of such circuit boards may make them difficult to arrange in three-dimensional space to ensure that cooling fluid reaches high heat-producing components. In addition, material and labor costs may be increased and the space efficiency that is often a benefit of liquid-cooling may not be realized.

There is therefore a need for an apparatus and method for cooling an electronic component mounted to a flexible wiring surface using spray-cooling or jet impingement cooling, which apparatus or method is integrated into the flexible wiring surface, is space-efficient and is simple to manufacture.

Summary of the Invention

According to an aspect of the present invention, the foregoing needs are addressed by an apparatus for cooling an electronic component which includes a flexible printed wiring device having a region sized to receive the electronic component and a channel disposed within the flexible printed wiring device. The channel has an inlet end and an outlet end and has an orifice disposed therein. The inlet end receives a fluid, the fluid is distributed to the orifice via the channel and the orifice directs the fluid toward the region, so that the fluid is in direct contact with the electronic component when the electronic component is disposed in the region.

Advantages of the present invention will become readily apparent to those skilled in the art from the following description of the preferred embodiment(s) of the invention which have been shown and described by way of illustration. As will be realized, the invention is capable of other and different embodiments, and its details are capable of modifications in various respects. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

Brief Description of the Drawings

FIG. 1 is a perspective view of a typical electronic component.

FIG. 2 is a perspective view of an apparatus for cooling the electronic component shown in FIG. 1 according to one aspect of the present invention and an illustration of the operation of the apparatus in conjunction with a cooling system having a closed-loop fluid flow.

FIG. 3 is a perspective view of an apparatus for cooling the electronic component shown in FIG. 1 according to another aspect of the present invention.

FIG. 4 is a perspective view of an apparatus for cooling the electronic component shown in FIG. 1 according to still another aspect of the present invention.

Detailed Description of the Preferred Embodiments

Turning now to the drawings, wherein like numerals designate like components, FIG. 1 is a perspective view of a typical electronic component **10**. Component **10** includes a number of terminals **14**, a base **17**, a cover **16** and one or more dies (not shown), which are protected by cover **16**.

Electronic component **10** may be, for example, an NPN Silicon Radio Frequency (RF) Power Transistor, such as a flangeless RF power transistor, available from Motorola, order number SRF701. References to electronic component **10** will be understood to apply not only to component **10** as depicted in FIG. 1, but also to differently-configured power transistors and to completely different components, including but not limited to passive

components, all types of integrated circuits, multi-chip modules and hybrid circuits.

As shown in FIG. 2, according to one embodiment of the present invention, the electronic component shown in FIG. 1 is mounted to a flexible printed wiring device **18**, such as a Kapton™ flexible sheet available from DuPont. Other suitable flexible materials include Nomex™ and Mylar™ materials, available from DuPont, silicone rubber and Teflon.

Flexible printed wiring device **18** preferably includes two layers **20** and **21** of a polyimide material such as Kapton™ flexible sheets. Alternatively, a single layer of polyimide material may be used. Device **18** may be referred to as having a first side **22** and a second side **23**.

Layer **20** may have electronic components **10** and other circuitry manufactured thereon according to well-known methods. For example, electrical wiring (not shown) may be etched into layer **20** and electronic components **10** may be physically and electrically connected to regions along the electrical wiring which are sized to receive the components **10**.

One or more fluid distributing channels **28** may be disposed within device **18**, between first and second layers **20** and **21**, for example. One method of forming channel **28** within flexible printed wiring device **18** is to apply an adhesive (not shown) to particular areas **30** between layers **20** and **21** and not to apply the adhesive to other areas. Then, channel **28** will be formed in areas without adhesive. Fluid distributing channel **28** will generally have an inlet end **32** and an outlet end **34** associated therewith, although multiple channels **28** may share the same inlet and outlet ends. Likewise, one channel **28** may have multiple inlet and outlet ends. Although layers **20** and **21** are preferably permanently

secured via adhesive, they may be attached using various other methods.

One or more orifices **36** are disposed within fluid distributing channel **28**, preferably under electronic components **10**. Orifices **36** may be holes formed to accelerate a fluid toward electronic components **10** or may be nozzles, or receptacles therefor, suitable for atomizing a fluid and spraying the atomized fluid onto components **10**. Orifices **36** may be any geometrical shape, including round or rectangular or another suitable shape.

Where nozzles are employed, they are preferably miniature atomizers such as simplex pressure-swirl atomizers, which may be made of any suitable material. An example of a suitable material is a metal such as stainless steel or brass. Simplex pressure-swirl atomizers are described in detail in U.S. Patent No. 5,220,804 to Tilton et al., incorporated herein by reference, and are commercially available from Isothermal Systems Research, Inc..

FIG. 2 further depicts operation of a closed-loop system for cooling electronic components **10**, according to a preferred embodiment of the present invention. A fluid pump **50**, which is connected via tube **52** to fluid inlet end **32**, supplies a coolant fluid (not shown), which may be any coolant such as water, antifreeze or a dielectric coolant, to fluid distributing channel **28**. Tube **52** may be coupled to fluid inlet end **32** using a barbed fitting (not shown), for example, or by any other suitable means.

Fluid passes into channel **28** and through orifice **36**, which accelerates the fluid and causes it to impinge on components **10**. The fluid may impinge directly onto the underside of electronic component **10**, or onto the topside of component **10**, according to the orientation in which component **10** is mounted to flexible printed wiring

device **18**. Additional heat transfer benefits may be realized merely from the flow of fluid through channels **28** in the proximity of components **10**. In addition, if additional fluid distributing channels **28** are located in the proximity of components **10**, they may enhance heat transfer from components **10**.

Orifice **36** is preferably configured such that the impingement point of the fluid is approximately aligned with the largest heat generating region or regions of component **10**. The fluid may be discharged from orifice **36** at an angle to first side **22** of device **18**, preferably at a perpendicular angle to first side **22**, and may component **10**, or may impact another thin member (not shown) disposed between component **10** and orifice **36**.

Heated fluid may continue on through distributing channel **28** before exiting device **18** through fluid outlet end **34**. A portion of the fluid may remain outside of channel **28** and may be collected by any suitable means.

A heat exchanger **53**, connected to pump **50** by tube **54** and to fluid outlet end **34** by tube **56**, receives fluid from fluid outlet end **34**. Heat exchanger **53** rejects heat from the fluid, returning it to primarily a liquid phase. Fan **58** may be used to extend the cooling capacity of heat exchanger **53**. Cooled fluid is supplied from heat exchanger **53** to pump **50**. Thus, a closed-loop flow of coolant is formed. It will be appreciated that at any given point the coolant may be a vapor, a liquid or a vapor and liquid mixture.

It is contemplated that any conventional means for providing flow of a coolant may be used in conjunction with the described embodiments of the present invention, and that more than one apparatus may be connected to a single source of coolant or that one or more sources of coolant may be connected to a single apparatus, for example, for redundancy purposes. It is also

contemplated that an open-loop fluid flow may be used with the various aspects of the present invention.

Sizes of fluid pump **50**, heat exchanger **53** and fan **58** should be selected based on heat removal and flow rate requirements. For example, a typical closed-loop fluid flow is 500 to 1000 milliliters per minute for 500 to 1000 Watts of heat dissipation. Pump and heat exchanger assemblies in various sizes, as well as acceptable tubing and fittings, are available from Cole-Parmer in Vernon Hills, Illinois, as well as other common sources.

The removal of heat directly from individual electronic components, rather than from an entire electronic module, helps to reduce operating temperatures of the components, increasing reliability through reduction of thermal variation and associated thermal stresses. In addition, efficient heat transfer at low flow rates may be realized.

The disclosed apparatus and method may also be made to be space-efficient, as shown in FIG. 3, which is a perspective view of an apparatus for cooling electronic components **10** according to another aspect of the present invention. As shown, flexible printed wiring device **18** has been folded along line **100**, so that a first region **101** and a second region **102** are formed on first side **22** and second side **23** of device **18**. Components **10** are disposed in first region **101** while fluid distributing channel **28** and orifices **36**, which may be nozzles, are located in second region **102**. Fluid distributing channel **28** and nozzles may be placed in any suitable location, however. In this manner, fluid may pass into channel **28** and through nozzles **36**, which atomize the fluid and cause it to impinge directly on components **10**. Nozzles **36** are preferably located from one to ten millimeters from components **10**, although a distance of six millimiters may be suitable.

In accordance with still another aspect of the present invention, a different space-efficient configuration of flexible device **18** is shown in FIG. 4. Electronic component **10** is disposed on first side **22** of device **18**, while orifice **36**, which may be a nozzle, has its opening on second side **23**. Fluid distributing manifold **28**, in which orifice **36** is situated, is disposed within flexible device **18**. Flexible device **18** is rolled into a cylindrical or spiral shape, so that a portion of first side **22** faces a portion of second side **23**, so that nozzle **36** discharges a fluid toward the electronic component. Nozzles **36** are preferably located from one to ten millimeters from components **10**, although a distance of six millimiters may be used. It may further be desirable to locate pump **50** in the center of cylindrically-positioned device **18**.

Thus, it can be seen that the various aspects of the present invention described herein which utilize flexible circuitry are easily manufactured and are space-efficient. And combining fluid cooling with electronics may reduce cost and complexity often associated with fluid delivery systems.

It is contemplated that wherever sealing and/or fastening may be required, numerous methods and materials may be used. For example, fasteners such as screws, compliant gaskets, ultrasonic welding, brazing, soldering or swaging may be utilized. And it will be understood that any combination of the aspects of the present invention may be used together on a single flexible device. In addition, it may be desirable to create a miniature "cold-plate" using a flexible substrate, having fluid distributing channels embedded therein.

It will be apparent that other and further forms of the invention may be devised without departing from the spirit and scope of the appended claims and their

equivalents, and it will be understood that this invention is not to be limited in any manner to the specific embodiments described above, but will only be governed by the following claims and their equivalents.

Claims

We claim:

1. An apparatus for cooling an electronic component, the apparatus comprising:

a flexible printed wiring device having a region sized to receive the electronic component; and

a channel disposed within the flexible printed wiring device, the channel having an inlet end and an outlet end and having an orifice disposed therein,

the inlet end receiving a fluid, the fluid distributed to the orifice via the channel, the orifice directing the fluid toward the region, so that the fluid is in direct contact with the electronic component when the electronic component is disposed in the region.

2. The apparatus according to claim 1, wherein the fluid is a dielectric fluid.

3. The apparatus according to claim 1, wherein the flexible printed wiring device comprises a first layer and a second layer.

4. The apparatus according to claim 3, wherein the first layer and the second layer are coupled via an adhesive.

5. The apparatus according to claim 4, wherein the channel is formed between the first layer and the second layer in an area where the adhesive is not present.

6. The apparatus according to claim 1, wherein the orifice comprises a nozzle.

7. The apparatus according to claim 6, wherein the nozzle atomizes the fluid.

8. The apparatus according to claim 7, wherein the fluid directed toward the region is in one of a single-phase or a two-phase.

9. The apparatus according to claim 1, wherein the electronic component is one of a power transistor and an integrated circuit.

10. The apparatus according to claim 1, wherein the flexible printed wiring device comprises a polyimide substrate.

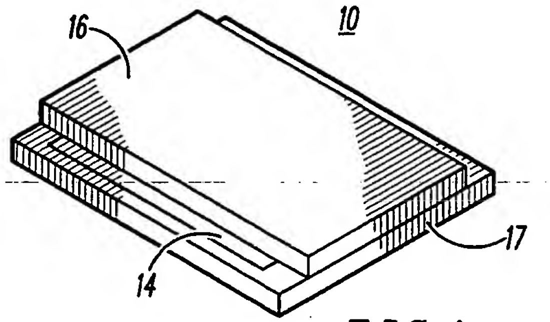

FIG.1
— PRIOR ART —

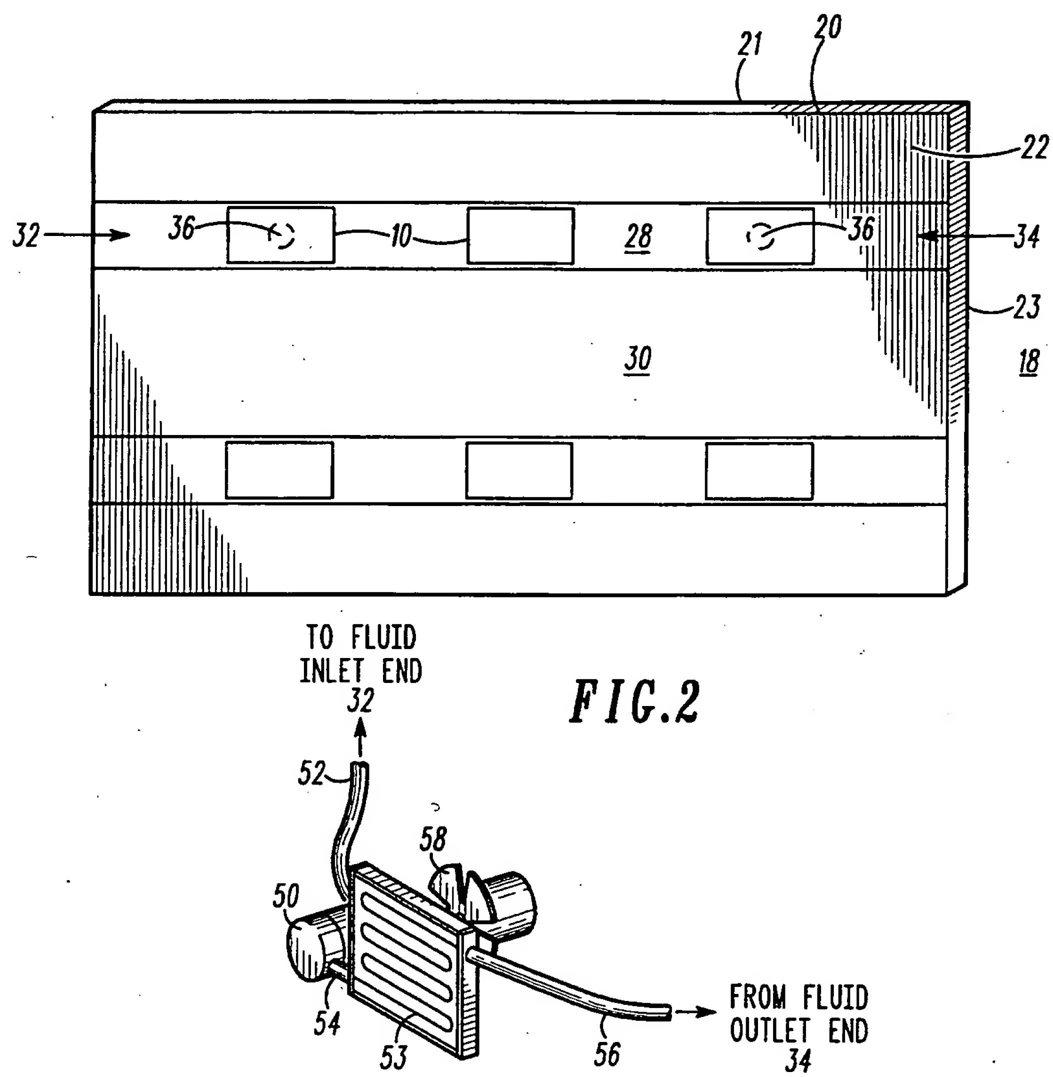

FIG.2

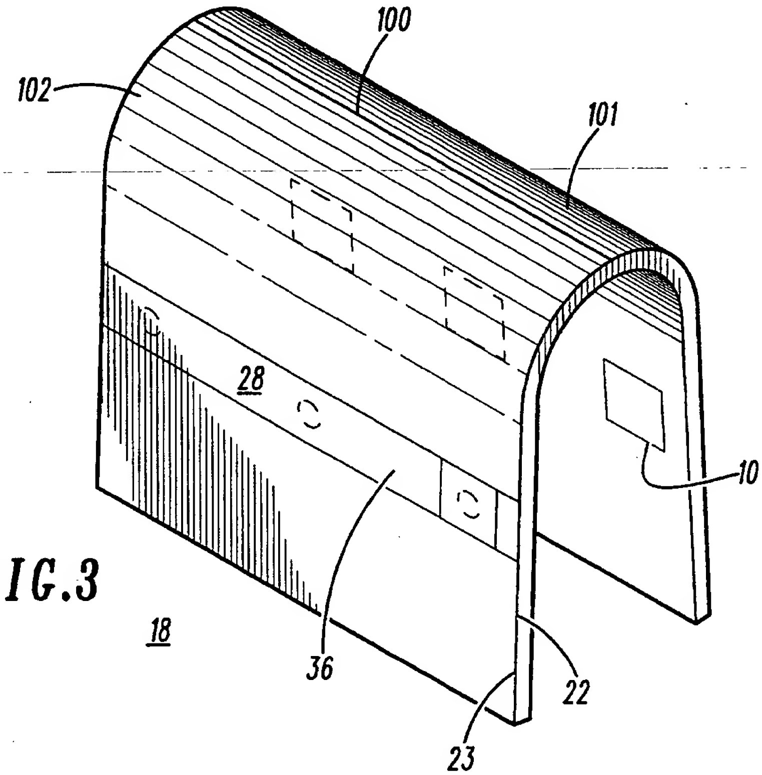

FIG.3

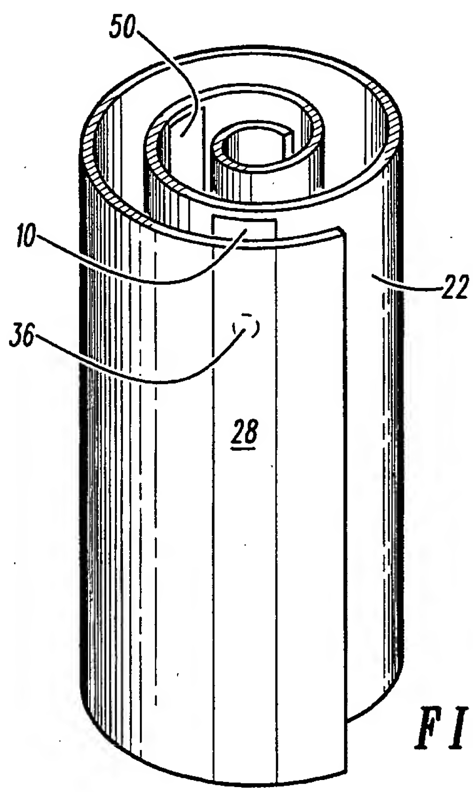

FIG.4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/04527

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :HO5K 7/20
US CL : 361/699,749
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 361/699,749

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,142,441 A (SEIBOLD ET AL) 25 August 1992, (25/08/92c) Cols.1-2	1-10
A	US 5,220,804 A (TILTON ET AL) 22 June 1993, (22/06/93) cols.6-9	1-10
A	US 5,453,911 A (WOLGEMUTH ET AL) 26 September 1995, (26/09/95) cols. 4-7	

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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